1.0

4.5
5.0
5.6
6.3

2.8

2.5

3.2

2.2

3.6

4.0

1.1

2.0

1.8

1.25

1.4

1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

United States
Department of
Agriculture

Forest Service

Forest
Products
Laboratory

Research
Paper
FPL 437

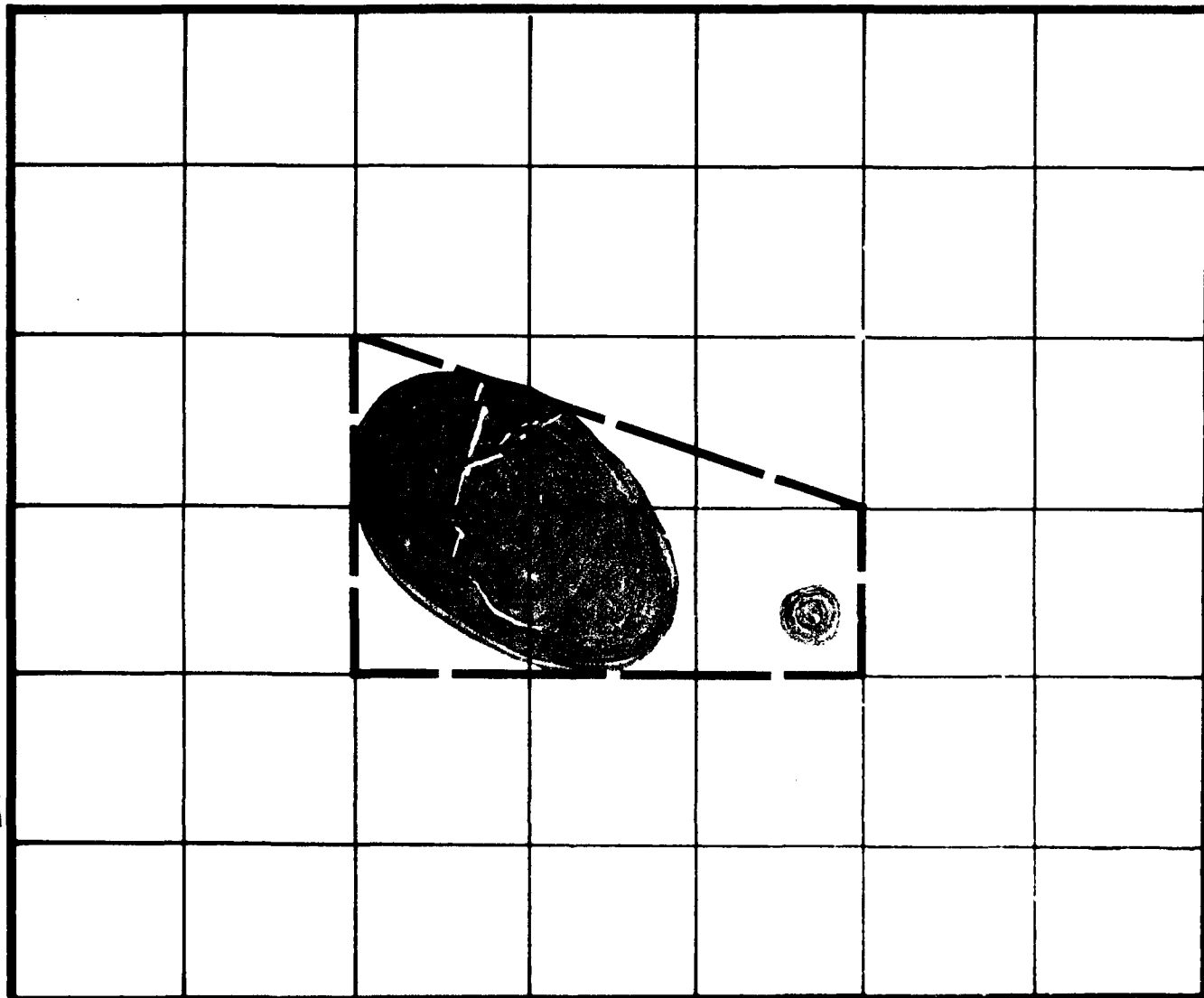# Maximum Cutting Yields for 6/4 Ponderosa Pine Shop Lumber

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PAMELA J. GIESE
and
RICHARD O. WOODFIN

Abstract

The moulding and millwork industries process nearly 1.3 billion board feet of Ponderosa Pine annually. Unfortunately, thousands of trees are harvested unnecessarily to compensate for inefficient processing. To help improve this situation, researchers at the Forest Products Laboratory developed maximum cutting yields for 6/4 Shop lumber in grades No. 1 Shop, No. 2 Shop, and No. 3 Shop. Yields were developed by building a representative 6/4 Shop lumber data base and simulating sawing of the lumber by the computer program OPTYLD. Results may be used to compare cutting yields between 6/4 Shop grades, to guide grade selection, and to estimate possible improvements in processing decisions. Results also encourage more automation in lumber processing.

This paper is part of a series on maximizing cutting yields of 5/4 and 6/4 Shop, and 6/4 Vertical Grain lumber.

Acknowledgment

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Maximum Cutting Yields for 6/4 Ponderosa Pine Shop Lumber

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Introduction

The losses that occur in the moulding and millwork industry from inefficient cutting practices are not only costly to the manufacturing operation but create a substantial and unnecessary drain on the national timber resource. Each year, an estimated 700 million board feet of timber are removed from the resource base just to compensate for inefficient processing. To foster better utilization of our timber resource, we need to encourage the changes necessary to update processing technology. Such updating includes use of automated systems that locate lumber defects, make processing decisions, and execute those decisions through computer-controlled sawing systems. This study was conducted to establish a foundation for automation in the moulding and millwork industry. The first objective was to build a representative data base of 5/4 and 6/4 Shop, and 6/4 Vertical Grain lumber presently being used by the industry. The 6/4 No. 3 and Better Shop grade data base was used for this report, which is the second of a series (6,7).[2] The second objective was to simulate the processing of this graded lumber with the computer program OPTYLD (5) to obtain the maximum clear cutting yield. Using the computer to evaluate every reasonable way of ripping and crosscutting each board, maximum cutting yields were developed that can be used to compare grade output and to evaluate different processing methods.

The literature is void of any information that even closely responds to these objectives. Previous attempts by researchers to obtain cutting yield data based on factory situations were hampered by the need to measure human performance and ability, and by the problems inherent when studying daily runs of lumber. Thus, individual board contribution could not be analyzed nor could repeated trials or alternative processing techniques be tried on the same set of study material. Now, however, the use of board data and the computer program OPTYLD enables repeated cutting simulations without the operator's biases affecting results.

Study Procedure

Sampling

A sample of 6/4 No. 3 and Better Shop lumber was collected over the geographical range of ponderosa pine (fig. 1). Mill cooperators selected the lumber from their inventories that they judged to be representative of their suppliers. The cooperating mills were located in Oregon, California, Arizona, and New Mexico. Because we decided the sampling method used for 5/4 Shop (6) was too cumbersome, a 10 percent systematic sampling method was employed for the 6/4 Shop to broaden the sampling base. Sample boards were obtained for measuring by selecting every 10th board from a standard shipping unit. This unit is defined as a strapped, dry, solid-stacked pile of lumber that contains approximately 2,500 board feet depending upon the length, width, and number of boards. We actually selected 16,086 board feet of 6/4 No. 3 and Better Shop lumber from numerous units. The volume distribution of boards sampled by grade is shown in table 1.

All sample material was reinspected by Quality Supervisors of the Western Wood Products Association to verify the grade and scale. If an inspector determined a board was misgraded, it was changed to the correct grade. We numbered all sample boards and identified the grade, gross surface measure, and net surface measure. We obtained board measure for the 6/4 Shop lumber by the standard procedure of multiplying net surface measure by 1.5.

Figure 1.—Distribution of ponderosa pine. (ML83 5059)

Measure First Face

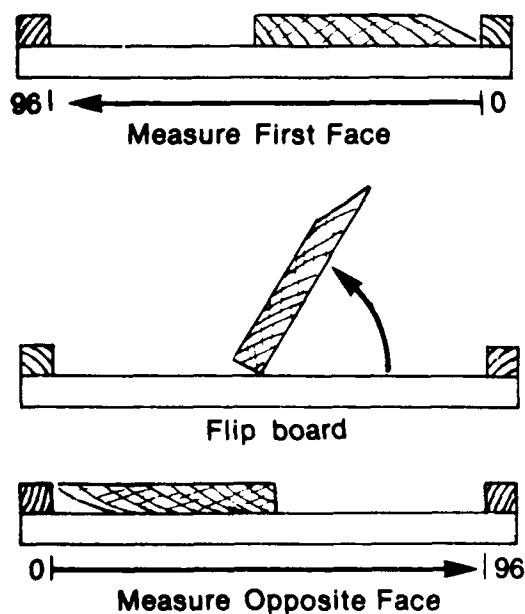**Flip board**

Measure Opposite Face

Figure 2.—Board measuring procedure. (M 148 959)

The actual widths and lengths of the boards sampled are summarized in table 2. Of the 16,086 board feet of 6/4 No. 3 and Better Shop measured, lengths ranged from 6 to 16 feet. Approximately 85 percent of the lumber was 16 feet in length. Sample board widths ranged from 5 to 24 inches, with approximately half of the total volume less than 11 inches, one-third between 11 and 14 inches, and the remaining one-sixth 15 to 24 inches wide (table 2).

Data Collection

A complete digital record was made of each selected board and all defects, including type of defect and its location to the nearest 1/4 inch. Board data recorded include board number, grade, unit number, width, length, gross surface measure, and net surface measure. Defects were measured to the nearest 1/4 inch on both faces of each board (fig. 2) using special measuring tables constructed for this purpose. All defects were tallied by type and the four coordinate points of a quadrilateral which contained the defect (fig. 3). The complete area of each board face was classified as either defect or clear to duplicate, as much as possible, what would be expected from a functional, automated lumber defect scanner. Any blemish not acceptable in a clear cutting was classified as defect and recorded.

Multiple defects were grouped within a single quadrilateral and assigned the code of the most predominant defect. Interpretation of the final location of some defect boundaries was necessary because the sampled lumber was "oversized" in thickness. This proved important when estimating the extent and severity of torn or chipped grain that might "dress out" versus "persist" after normal surfacing.

Simulated Board Processing Program (OPTYLD)

To obtain the maximum clear cutting yields for making the comparisons between grades of Shop lumber, we used the computer program OPTYLD that Giese and McDonald (5) developed specifically for this purpose. This computer model simulates the three basic sawing operations— multiple rip, crosscut, and rerip—typically used in processing 6/4 Shop-graded lumber.

Constraints of this computer program to analyze the data are
   —only clear, two-face cuttings can be obtained.
   —1/4-inch increments used to describe board size, defect coordinates, saw kerf, and cutting dimensions.
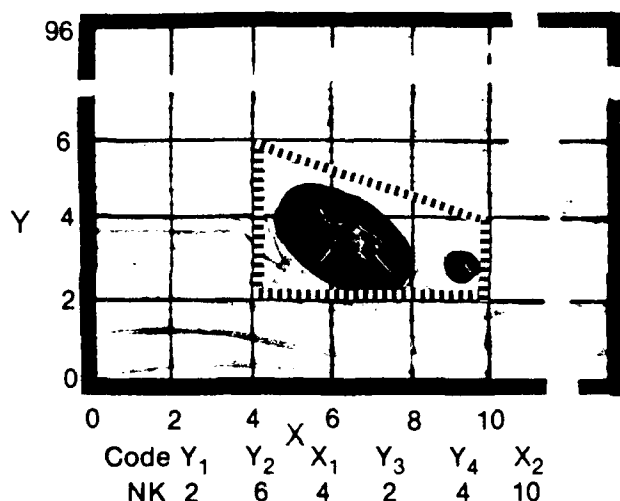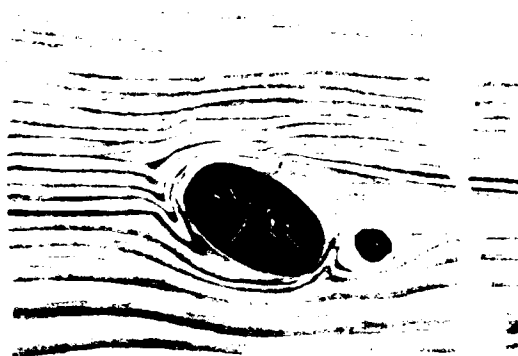   —maximum board size of 24 inches wide and 16 feet long

Figure 3.—Defect measuring procedure.
(M 148 955, M 148 954)

Code	Y$_1$	Y$_2$	X$_1$	Y$_3$	Y$_4$	X$_2$
NK	2	6	4	2	4	10

The computer model combines the board and defect data of both board faces and selects the sawing solution that results in the maximum value and/or yield of clear cuttings. To obtain the best sawing solution, all valid combinations of ripping then crosscutting are calculated for each board, and the value or yield of clear cuttings obtainable from these combinations is compared.

For the 6/4 Shop, we selected five cutting widths for multiple ripping: 2.50, 3.00, 3.50, 4.50, and 4.75 inches. These widths generally represent industry practice. (Additional interpolations are necessary for widths not selected.) Five rip saws were available for up to five rips, plus a 1/4-inch edging allowance to straighten one edge of each board. Random length cuttings were calculated— 9 inches and longer in increments of 1 inch, but not to exceed 84 inches. To be consistent with present processing practice, the reripping feature of the computer

program was used for calculating salvageable clear material after the maximum ripping and crosscutting solution was calculated. The reripping widths were 1.75, 2.50, 3.00, 3.50, and 4.50 inches. We developed a cutting value index (table 3) to compare the value of different size cuttings so that the highest return from each board could be calculated. These values, which have no units, represent current industry practice.

Table 1.—Sample data, 6/4 Ponderosa Pine Shop

Grade	Number of boards	Total volume	Average volume per board
		------ -Board feet¹ - - - - - -	
No. 1	107	2.984	27.9
No. 2	346	8.136	23.5
No. 3	238	4.966	20.9
Combined	691	16.086	23.3

¹ Scaled net surface measure times 1.50

Table 2.—Board size distribution, 6/4 Ponderosa Pine Shop

Width	Board length			Length distribution		
	< 16 feet	16 feet	Total	< 16 feet	16 feet	Total
In.	- - - -Board feet - - - - -			- - - - - - -Pct - - - - - - -		
4-10	1,643	7,050	8,693	10	44	54
11-14	607	4,100	4,707	4	25	29
15-24	82	2,604	2,686	1	16	17
Total	2,332	13,754	16.086	15	85	—

Table 3.—Relative cutting value index, 6/4 Ponderosa Pine Shop

Width	Cutting length (in.)								
	9-12	13-19	20-26	27-35	36-47	48-59	60-71	72-83	84
In.	- - - - - - -Value¹ per 1,000 square feet - - - - - - - -								
2.50	800	810	820	840	860	880	1000	1030	1150
3.00	800	810	820	840	860	880	1000	1030	1150
3.50	810	830	840	860	880	910	1040	1070	1200
4.50	820	840	850	870	890	930	1080	1120	1250
4.75	825	845	855	875	895	950	1100	1145	1300

¹ Value has no units.

Maximum Cutting Yield by Grade

The maximum clear cutting yields were computed for each grade by computer simulation using a realistic set of mill requirements. These maximum yields were compiled from the individual board-by-board solutions that maximized the value. Cutting values from the cutting value index were used to make cutting solution decisions that would yield larger cuttings. Individual board cutting solutions were summarized for each grade by the number of cuttings, total value of cuttings, yield per 1,000 board feet, percent cutting area to board area, and total lineal feet of cuttings per 1,000 board feet (tables 4-8). Each summarization provides results germane to different objectives. Mill managers and operators can use these results to make production, purchasing, and processing decisions, keeping in mind the limitations previously mentioned. The actual number of cuttings obtained from all boards by cutting width and length classes are shown in table 4. These are maximum yields that can only be expected for the sample of boards used and the options used in the computer program.

Table 4.—Total clear cutting yield—piece count, 6/4 Ponderosa Pine Shop

Width	Length (in.)								
	9-12	13-19	20-26	27-35	36-47	48-59	60-71	72-83	84
In.						No. of cuttings			
NO. 1 SHOP									
107 BOARDS, BOARD MEASURE — 2,984 BOARD FEET									
1.75	76	59	19	8	5	4	3	1	2
2.50	81	111	81	109	74	62	45	32	70
3.00	35	39	35	28	35	24	21	7	33
3.50	35	49	36	34	38	26	30	28	49
4.50	29	31	31	34	21	16	16	9	43
4.75	13	28	20	28	22	9	5	7	34
NO. 2 SHOP									
346 BOARDS, BOARD MEASURE — 8,136 BOARD FEET									
1.75	328	221	81	48	23	9	1	2	2
2.50	572	655	392	398	344	179	126	64	137
3.00	189	248	159	166	124	82	50	25	62
3.50	231	269	164	140	113	63	67	42	83
4.50	40	66	42	35	31	9	20	6	31
4.75	46	72	36	35	32	20	11	5	30
NO. 3 SHOP									
238 BOARDS, BOARD MEASURE — 4,966 BOARD FEET									
1.75	322	199	53	26	15	1	0	1	0
2.50	468	605	389	264	198	95	60	29	30
3.00	179	215	134	91	83	36	29	15	19
3.50	134	189	104	70	56	23	17	8	18
4.50	26	40	12	22	9	9	13	2	4
4.75	33	25	25	11	12	8	1	1	2

Table 5 — Total clear cutting values, 6/4 Ponderosa Pine Shop

Width	Length (in.)								
	9-12	13-19	20-26	27-35	36-47	48-59	60-71	72-83	84
in.						Value			
NO. 1 SHOP									
107 BOARDS, TOTAL VALUE[1] 1,610									
1.75	8	9	4	2	2	2	2	1	2
2.50	12	25	27	51	46	51	52	46	122
3.00	6	11	14	16	26	24	29	13	69
3.50	8	16	17	22	33	32	52	58	125
4.50	8	13	19	29	23	26	36	25	147
4.75	4	13	12	25	26	15	12	20	122
NO. 2 SHOP									
346 BOARDS, TOTAL VALUE[1] 3,713									
1.75	33	32	18	15	9	5	1	2	2
2.50	85	151	131	184	216	150	149	91	240
3.00	34	69	63	92	93	82	70	43	130
3.50	49	86	78	90	100	75	114	88	211
4.50	11	28	26	30	35	14	45	16	106
4.75	14	32	23	32	38	34	26	14	108
NO. 3 SHOP									
238 BOARDS, TOTAL VALUE[1] 1,877									
1.75	32	29	12	8	6	0	0	1	0
2.50	70	138	130	121	124	80	70	42	52
3.00	32	60	53	50	61	36	41	26	40
3.50	28	61	50	46	50	28	29	17	46
4.50	7	17	7	18	10	14	29	6	13
4.75	10	11	16	10	14	14	2	3	7

[1] Value has no units

The actual accumulated value for each cutting width and length class by grade is shown in table 5 and reflects the relative cutting recovery by cutting size. Comparisons can only be made within a grade as these are total values, not values per unit board volume. This table is presented as an example of the type of information available from the computer program for those interested in determining the effects of different processing options, a different value table, or different kerf widths. For example, two different sets of ripping widths can be directly compared after running both through the computer program OPTYLD to obtain the total clear cutting values.

Table 6 shows the number of cuttings per thousand board feet. This table is consistent with the needs of mill operators and managers where their inventory, sales, and production records are on a board-measure basis. With this table, yields between lumber grades can be directly compared. As these are maximum cutting yields from the computer, they cannot be considered expected yields in a commercial production.

Cutting yields for cuttings other than those calculated in this study can be estimated from table 6. However, only minimum yields are then obtainable. For example, in table 6 for No. 1 Shop, the 11.4 cuttings 4.75 by 84 inches will make at least twice that many cuttings 37 to 42 inches long. Naturally, shorter cuttings cannot be summed to get longer cuttings, nor can cuttings less than 9 inches in length be counted as usable material because of computer constraints. Widths also can be subdivided similarly to lengths, but only in multiples or fractions of widths shown.

The distribution of clear cuttings recovered by grade is obtained from the total cutting area within a size class as a percent of the total area of the boards (table 7). Maximum cutting volumes expected by cutting size by grade are calculated directly from these percentages. For example, 46.3 board feet (4.63/100 × 1,000) of the 4.75- by 84-inch cuttings could be expected from 1,000 board feet of No. 1 Shop, whereas 1,000 board feet of No. 2 Shop would yield only 14.9 board feet (1.49/100 × 1,000) of the same cutting. The relative distribution of the required cuttings of a cutting bill from a grade can also be obtained for best grade recovery and raw material selection.

Table 6.—Cutting yield to board measure, 6/4 Ponderosa Pine Shop

Width	Length (in.)								
	9-12	13-19	20-26	27-35	36-47	48-59	60-71	72-83	84
In.	- - - - - - - -Cuttings per 1,000 board feet - - - - - - - -								
NO. 1 SHOP									
107 BOARDS, BOARD MEASURE — 2,984 BOARD FEET									
1.75	25.5	19.8	6.4	2.7	1.7	1.3	1.0	0.3	0.7
2.50	27.2	37.2	27.2	36.5	24.8	20.8	15.1	10.7	23.5
3.00	11.7	13.1	11.7	9.4	11.7	8.0	7.0	2.4	11.1
3.50	11.7	16.4	12.1	11.4	12.7	8.7	10.1	9.4	16.4
4.50	9.7	10.4	10.4	11.4	7.0	5.4	5.4	3.0	14.4
4.75	4.4	9.4	6.7	9.4	7.4	3.0	1.7	2.4	11.4
NO. 2 SHOP									
346 BOARDS, BOARD MEASURE — 8,136 BOARD FEET									
1.75	40.3	27.2	10.0	5.9	2.8	1.1	0.1	0.2	0.2
2.50	70.3	80.5	48.2	48.9	42.3	22.0	15.5	7.9	16.8
3.00	23.2	30.5	19.5	20.4	15.2	10.1	6.2	3.1	7.6
3.50	28.4	33.1	20.2	17.2	13.9	7.7	8.2	5.2	10.2
4.50	4.9	8.1	5.2	4.3	3.8	1.1	2.5	7	3.8
4.75	5.6	8.8	4.4	4.3	3.9	2.5	1.4	6	3.7
NO. 3 SHOP									
238 BOARDS, BOARD MEASURE — 4,966 BOARD FEET									
1.75	64.8	40.1	10.7	5.2	3.0	0.2	0.0	0.2	0.0
2.50	94.2	121.8	78.3	53.2	39.9	19.1	12.1	5.8	6.0
3.00	36.0	43.3	27.0	18.3	16.7	7.2	5.8	3.0	3.8
3.50	27.0	38.0	20.9	14.1	11.3	4.6	3.4	1.6	3.6
4.50	5.2	8.0	2.4	4.4	1.8	1.8	2.6	.4	8
4.75	6.6	5.0	5.0	2.2	2.4	1.6	2	2	4

Table 7.—Cutting size distribution, 6/4 Ponderosa Pine Shop

Width	Length (in.)								
	9-12	13-19	20-26	27-35	36-47	48-59	60-71	72-83	84
In.	Cutting area as a percent of board area								
NO. 1 SHOP									
107 BOARDS, TOTAL BOARD AREA — 2,036 SQUARE FEET									
1.75	0.48	0.55	0.26	0.15	0.12	0.12	0.11	0.05	0.10
2.50	.72	1.48	1.56	2.84	2.57	2.1	.46	2.19	5.01
3.00	.39	.66	.85	.41	1.48	1.29	1.41	.48	2.84
3.50	.45	.91	.98	1.21	1.85	1.72	2.31	.52	4.91
4.50	.49	.78	1.07	1.64	1.24	1.32	1.60	1.06	5.54
4.75	.23	.76	.73	1.40	1.46	.78	.52	.87	4.63
NO. 2 SHOP									
346 BOARDS, TOTAL BOARD AREA — 5,565 SQUARE FEET									
1.75	0.75	0.74	0.40	0.32	0.09	0.12	0.01	0.03	0.04
2.50	1.89	3.27	2.80	3.85	4.41	2.95	2.58	1.54	3.59
3.00	.75	1.49	1.35	1.92	1.91	1.63	1.22	.72	1.95
3.50	1.08	1.84	1.65	1.85	2.02	1.45	1.91	1.41	3.04
4.50	.24	.59	.54	.61	.70	.27	.73	.25	1.46
4.75	.29	.68	.48	.65	.77	.64	.42	.23	1.49
NO. 3 SHOP									
238 BOARDS, TOTAL BOARD AREA — 3,413 SQUARE FEET									
1.75	1.21	1.09	0.43	0.28	0.22	0.02	0.00	0.03	0.00
2.50	2.53	4.89	4.53	4.13	4.14	2.57	1.98	1.14	1.28
3.00	1.16	2.11	1.87	1.71	2.04	1.16	1.15	.71	.97
3.50	1.02	2.13	1.71	1.55	1.63	.88	.78	.44	1.08
4.50	.25	.58	.25	.61	.34	.42	.78	.14	.31
4.75	.34	.38	.54	.32	.46	.42	.06	.07	.16

[1] Board area determined from board coordinates and is not the same as scaled surface measure.

Total lineal feet of the random length cuttings by grade and width per 1,000 board feet are shown in table 8. These results include the rerip yield and were determined by summing the individual cutting lengths. Again, the relative differences and similarities that occur between the three Shop grades are shown in this table. The lineal footage data are used to evaluate different computer runs where cutting options are being compared.

Maximum Cutting Yield by Board Size

Because the maximum cutting yield is available for each board in the Ponderosa Pine data base, the results are presented by board size for the three Shop grades. The yield of clear cuttings from any given board depends on the size and location of clear areas and the size of the board. Because the timber resource is changing to smaller diameter, second-growth trees, more narrow width lumber is being processed. The effect on the molding and millwork industries is lower yields and smaller cuttings.

The percent of maximum cutting yields shows relatively little difference as surface measure (board size) changes within each grade. Individual board percentages and average percentage plotted for each surface measure show the total variation in the board data and in the average plotted for No. 1 Shop.

Board value, plotted against surface measure (figs. 7-9), shows the correlation between low-value small boards and high-value large boards. This is a direct result of the size and number of clear cuttings these boards can produce. Individual board values and average value plotted for each surface measure show the total variation by board and the relative difference between the grades. The effect of changing board size can be determined by resampling a Shop grade, calculating board surface measure, and estimating yield and value from these data.

Recovery

The differences that occur between the Shop grades of 6/4 lumber are evident from the value obtained per unit area of cuttings, the recovery percentages, and the computed cutting values per board measure as they are shown in table 9. Because the raw material for the moulding and millwork industry is purchased on a per 1,000 board feet basis, the resulting cutting values obtained from the study boards are shown based on the same measure. (Remember, these values have no units and are derived using values from the cutting value index) (table 3).

The value per unit of clear cuttings obtained for each grade is calculated by:

$$\frac{V}{A} = UV \tag{1}$$

where V = total value of clear cuttings
A = total board area in clear cuttings (ft²)
UV = value per unit of clear cutting

For each grade, these values are 1.025 for No. 1, 0.956 for No. 2, and 0.902 for No. 3. These values do not vary greatly but do reflect the cutting sizes and cutting values obtained by grade.

Recovery of clear cuttings relative to the board footage in the sample is obtained by:

$$\frac{A}{B} \times 100 = R \tag{2}$$

where A = total board area in clear cuttings (ft²)
B = board feet
R = percent recovery of cutting area to board feet

By grade, maximum recovery percents are 52.6 for No. 1, 47.7 for No. 2, and 41.9 for No. 3 Shop. These percentages reflect differences due to grading rules applied by the grading association. To convert these values to percent recovery of cuttings in board feet, multiply the percentages by 1.5.

Finally, the cutting value expected for 1,000 board feet is calculated by:

$$\frac{R \times 1,000}{100} \times UV = V/M \tag{3}$$

where R = percent recovery (from eq. [2])
UV = value per unit of clear cutting (from eq. [1])
V/M = value per 1,000 board feet

By grade, values per 1,000 board feet are 540 for No. 1, 456 for No. 2, and 378 for No. 3. Assuming the relative value index table used was reasonably accurate, these cutting values should represent the absolute differences in yields between these grades. The actual value recovered by an individual operation may be substantially different from these figures, due to processing methods and acceptance of other than clear cuttings.

Reripping

In most millwork and moulding operations, the primary breakdown of lumber to obtain clear cuttings involves ripping lumber full length followed by crosscutting. After crosscutting, all material is then either a clear cutting or classed as defective. The defective material may contain clear areas that meet or exceed the minimum clear cutting size but are unobtainable by the rip, then crosscut, operations. These areas can be salvaged by an additional ripping operation, called reripping, or backripping. Usually the crosscut operator identifies the salvage pieces, cuts them to length, and sends them to the rerip operation

Table 8.—Total lineal feet of cuttings to board measure, 6/4 Ponderosa Pine Shop

Width	No. 1	No. 2	No. 3
In.	– – – –Lineal feet per 1,000 board feet – – – – –		
1.75	91	122	154
2.50	708	883	897
3.00	283	354	354
3.50	399	381	264
4.50	269	99	68
4.75	196	98	48

Table 9.—Recovery from 6/4 Ponderosa Pine Shop

	B	V	A	UV	$\frac{V}{A}$	R	$\frac{100A}{B}$	V/M	$\frac{1,000V}{B}$
Shop grade	Total board measure	Total value of cuttings	Total area of cuttings	Value¹ per unit cutting		Recovery cutting area to board measure		Cutting value¹ per 1,000 board feet	
	Board feet	V¹	Ft²	V/ft²		Pct			
No. 1	2,984	1,610	1,570	1.025		52.6		540	
No. 2	8,136	3,713	3,882	.956		47.7		456	
No. 3	4,966	1,877	2,082	.902		41.9		378	

¹ Value has no units (see table 5).

Figure 4.—Yield distribution—No. 1 Shop. 6 4
Ponderosa Pine. (ML83 5120)

Figure 7.—Value distribution—No. 1 Shop. 6 4
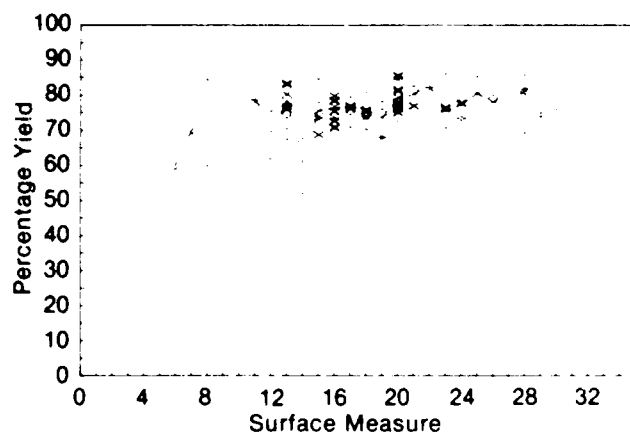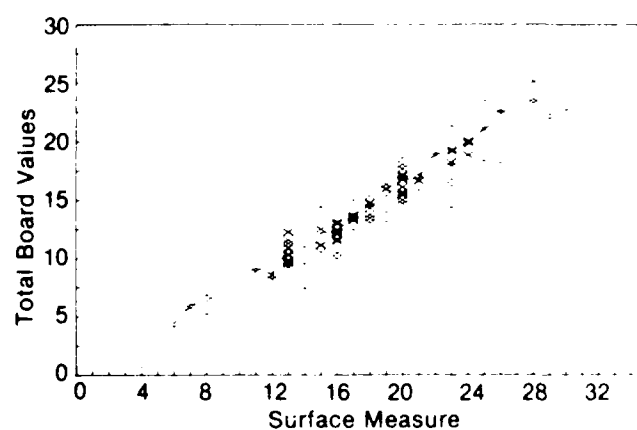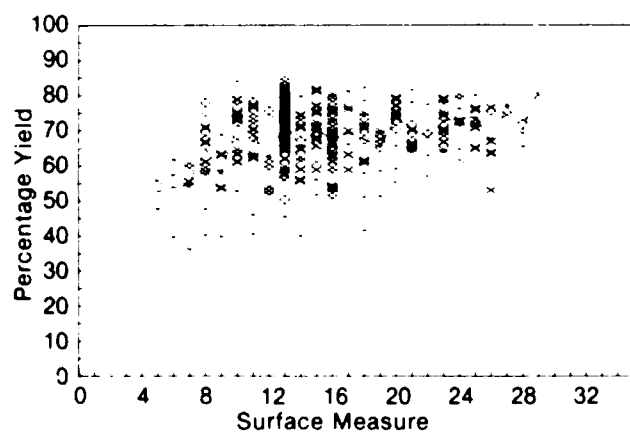Ponderosa Pine. (ML83 5123)

Figure 5.—Yield distribution—No. 2 Shop. 6 4
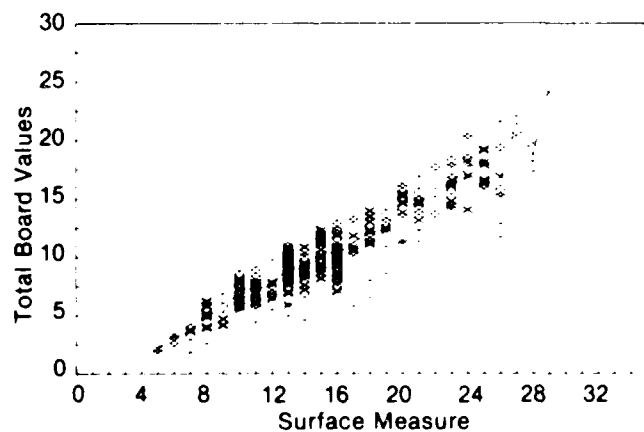Ponderosa Pine. (ML83 5121)

Figure 8.—Value distribution—No. 2 Shop. 6 4
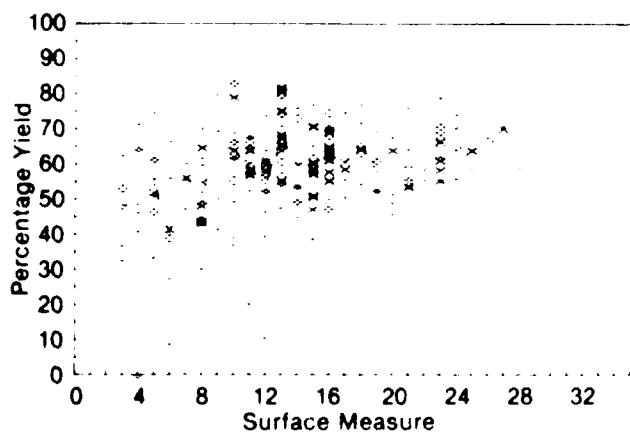Ponderosa Pine. (ML83 5124)

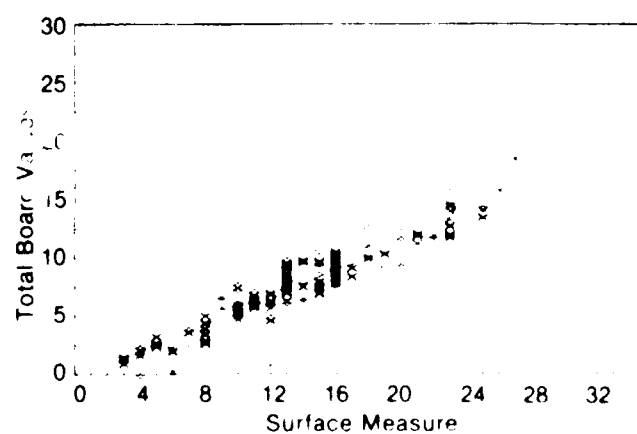Figure 6.—Yield distribution—No. 3 Shop. 6 4
Ponderosa Pine. (ML83 5122)

Figure 9. Value distribution—No. 3 Shop. 6 4
Ponderosa Pine. (ML83 5125)

Summary

Results presented so far in this report have been the combined rip and rerip clear cutting yields. The reripping results are shown as the number of rerip cuttings obtained per 1,000 board feet by cutting size (table 10). The rerip widths include the narrower 1.75-inch width. The significance of a reripping operation shows up in the rerip results in both additional volume and value (table 11). Cutting yield increases of 3.6 to 7.3 percent of the total cutting yield and value increases of 2.8 to 6.6 percent were directly attributable to the reripping operation.

Compilation of this yield study provides original yield information by grade for 6/4 Shop lumber. Because these yields were obtained by the computer, the production decisions were consistent and are free from human biases and problems inherent when studying daily runs of lumber. An example of applying this information is the a mill operation decision to forego the common practice of processing a mixture of No. 3 and Better Shop lumber and instead processing a straight No. 3 Shop and putting the No. 1 and No. 2 Shop back on the market for a higher return.

This study also provides an extensive data base for 6/4 Shop boards. This data base will encourage more study of improved utilization methods and the testing of these methods on the same boards. Such tests consist of evaluating alternative products and processes, including an ongoing evaluation of automated defect detection. We hope that researchers and managers will realize, through this series of reports, the value of the currently available tools in pursuing improved utilization.

Any improved utilization practices implemented will foster significant savings in timber resources. Timber annually lost to inefficient processing is a resource wasted which must be replaced with other growing stock of the same or a substitute species.

Table 10.—Rerip yield to board measure, 6/4 Ponderosa Pine Shop

Width	Length (in.)								
	9-12	13-19	20-26	27-35	36-47	48-59	60-71	72-83	84
in.	------- Rerip cuttings per 1,000 board feet -------								
			NO. 1 SHOP						
	107 BOARDS BOARD MEASURE				2,984 BOARD FEET				
1.75	25.5	19.8	6.4	2.7	1.7	1.3	1.0	0.3	0.7
2.50	3.7	3.7	3	1.0	0	3	0	0	0
3.00	1.7	.7	0	0	0	0	0	0	0
3.50	3.0	2.0	3	0	0	0	0	0	0
4.50	0	0	0	0	0	0	0	0	0
4.75	—	—	—	—	—	—	—	—	—
			NO. 2 SHOP						
	346 BOARDS BOARD MEASURE				8,136 BOARD FEET				
1.75	40.3	27.2	10.0	5.9	2.8	1.1	0.1	0.2	0.2
2.50	7.1	3.3	1.0	5	4	0	0	0	0
3.00	5.0	2.5	1	2	2	0	0	0	0
3.50	2.1	1.1	*	1	1	0	0	0	0
4.50	0	0	0	0	0	0	0	0	0
4.75	—	—	—	—	—	—	—	—	—
			NO. 3 SHOP						
	238 BOARDS BOARD MEASURE				4,965 BOARD FEET				
1.75	64.8	40.1	10.7	5.2	3.0	0.2	0.0	0.2	0.0
2.50	9.1	5.2	1.8	1.0	6	0	0	0	2
3.00	4.6	2.0	2	4	2	0	0	0	0
3.50	1.8	1.2	4	0	0	0	0	0	0
4.50	0	0	0	0	0	0	0	0	0
4.75	—	—	—						

Table 11.—Rip and rerip yield summary, 6/4 Ponderosa Pine Shop

Shop grade	Maximum cutting yield			Value		
	Rip	Rerip	Rerip	Rip	Rerip	Rerip
	Ft²	Ft²	Pct			Pct
No. 1	1,514	56	3.6	1,565	45	2.8
No. 2	3,683	199	5.1	3,664	242	6.6
No. 3	1,928	153	7.3	1,963	134	6.8

[1] Value has no units (see table 5).

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